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Tutorial
Prototyping IoT devices on GNU/Linux

Embedded Linux Conference
#LFELC, Berlin, Germany <2016-10-13>

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Hallo Welt!

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- Philippe Coval
  - Software engineer for Samsung OSG
    - Belongs to SRUK team, based in Rennes, France
    - Ask me for IoTivity support on Tizen platform and others
  - Interests
    - Libre Soft/Hard/ware, Communities, Interoperability
      - DIY, Embedded, Mobile, Wearables, Automotive...
  - Find me online
    - https://wiki.tizen.org/wiki/User:Pcoval

Newbies, makers, hackers welcome !

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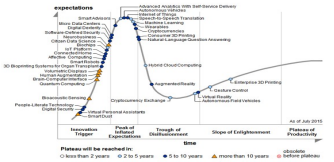
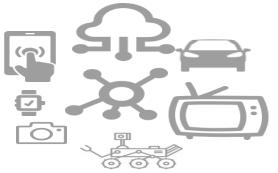


- This “IoT” talk is not about:
  - Market share, prospects, growth, figures
    - Monetize data with cloud, analytics, big data, machine learning
      - Security, privacy, trust, Skynet, singularity or any concerns
  - Architectures, services or designs
    - Comparison of protocols or implementations
    - Tizen the “OS of Everything” (unless if asked)



- It's about **quick** **prototyping** for proof of concepts:
  - Learn by doing from scratch, DIY: software, hardware, electronics
  - Feedback on previous **experimentations** from embedded developer
  - Front door to a project of 435K+ lines of code and ~500 pages of specifications

Agenda

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- Prototyping
- Simplest example
- Implementation
- Hardware integration
- Demonstration
- Q&A

Motivations for prototyping

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- *NOT* making a mass produced IoT device at 1st shot
  - Low cost (<10 $), low consumption (mW), high level of security
- Validate concepts with **relaxed constraints**
  - In **friendly environment** (ie: tools, security or connectivity shortcuts)
  - Validate, show, gather feedback, stress, benchmark, adapt, iterate
- Think of use cases first?
  - Or experiment with what can technology can provide? Be inspired!
- Topics and Ideas?
  - Controlling, monitoring, convergence, network of sensors, behaviors, AI...

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"**Simplicity**
is the ultimate sophistication."
~Leonardo da Vinci

Simplest use case

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- From the blinking led
- To a remote controlled switch
  - GPIO, LED, Relay, Motor, Fan, Home Appliance...
  - Simple functions: On/Off
- To a flip/flop relay controlled by multiple clients
  - Notification of change in real time
  - Consistent toggle feature
- Identified problems, are half solved :
  - **Sharing** hardware resource(s) through a seamless **connectivity**

IoTivity : Connectivity between devices

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- Apache-2 licensed C/C++ Implementation
  - Of Open Connectivity Foundation's **standard** (OCF~OIC)

- Many features:
  - **Discovery** (IETF RFC7252 / IP Multicast)
  - Communication (RESTfull API on CoAP) w/ Security (DTLS)
  - Transports (IP, WiFi, BT, BLE, Zigbee...)
  - Data/Device management, web services, cloud, plugins...

- Today we'll use only few features to connect our thing

OCF Vocabulary is all about resources

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- Resource is representing
  - virtual object (ie: logical states)
  - physical data (ie: actuator, sensors)
  - hybrid (ie: soft sensors)
- Resource entity
  - Each can be accessed by an URI
  - Has a resource type identifier
  - Is composed of **properties**
    - type, name, value

- More concepts
  - Model to describe
    - Resource's **interface**
      - Properties & allowed ops
      - GET, POST, PUT, params...
  - Groups, collections, links
  - Scenes, Things manager
  - Many more services

Don't reinvent the wheel

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- OCF's Standardized data **model** repository
  - http://www.oneiota.org/
  - **RESTful** API Modeling Language (RAML > JSON)
  - To be used with a simulator (ATM)
- Search for existing models
  - https://github.com/OpenInterConnect/IoTDataModels
  - http://www.oneiota.org/documents?q=switch
    - binarySwitch.raml includes oic.r.switch.binary.json
    - http://www.oneiota.org/revisions/1580

OCF Model defines switch resource type

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```
{ "id": "http://openinterconnect.org/iotdatamodels/schemas/oic.r.switch.binary.json#",
  "$schema": "http://json-schema.org/draft-04/schema#",
  "description" : "Copyright (c) 2016 Open Connectivity Foundation, Inc. All rights reserved.",
  "title": "Binary Switch",
  "definitions": {
      "oic.r.switch.binary": {
        "type": "object",
        "properties": {
          "value": {
            "type": "boolean",
            "description": "Status of the switch"
} } } } // ...
```

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"The secret of getting ahead
is getting **started**."
~ Mark Twain

Time to make choice

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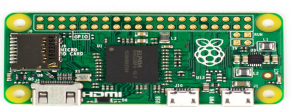
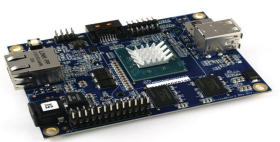
- OS? https://wiki.iotivity.org/os
  - None: for Microcomputers (MCU: Bare metal)
  - **GNU/Linux** : Debian/Ubuntu, Yocto, Tizen, OpenWRT...
  - Or others FLOSS or not
- Hardware? https://wiki.iotivity.org/hardware
  - Arduino (MCU) : C API
  - Cheap **Single Board Computer** (CPU): C++ API (or C API too)
    - IO: GPIO, I2C, SPI, Antennas, Daughter-boards...
    - RaspberryPI (0|1|2|3), MinnowMax (OSHW), Edison, Samsung ARTIK (5|10), ...





Get your hands on IoTivity!

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- Get and build libraries: https://wiki.iotivity.org/build
  - Download sources and dependencies
    - Build it using **scons**
  - Or if OS shipping IoTivity (Tizen, Yocto, ...)
    - Use it a regular **library** (CPPFLAGS & LDFLAGS)
- Look at tree: https://wiki.iotivity.org/sources
  - Samples apps: resource/examples
  - C++ SDK: resource/resource/src
  - C SDK: resource/csdk

Typical flow

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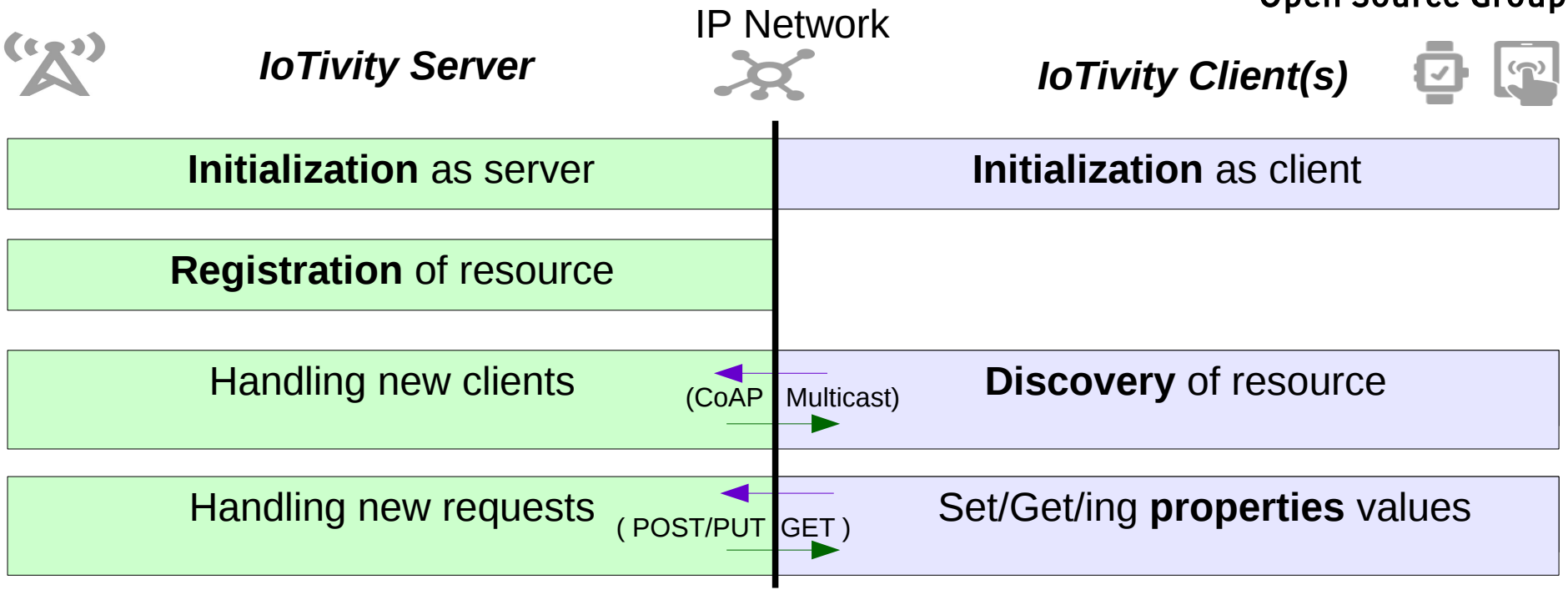

- Minimal example project to base on: git clone iotivity-example
  - Simple C (uses callbacks) or C++11

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"Talk is cheap.
Show me **the code**."
~ Linus Torvalds

Initialization

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IoTivity Server

IP Network

IoTivity Client(s)

OCPlatform::Configure(OC::PlatformConfig)	OCPlatform::Configure(OC::PlatformConfig)

```
class IoTServer {
  int main() { init(); … }

  OC::PlatformConfig mPlatformConfig;
  void init() {
    mPlatformConfig =  OC::PlatformConfig
        (OC::ServiceType::InProc,
         OC::ModeType::Server, // different that C
        "0.0.0.0", 0, // default for all subnets / ifaces
         OC::QualityOfService::LowQos //or HighQos
        );
    OCPlatform::Configure(mPlatformConfig);
  }
};
```

```
class IoTClient {
  int main() { init(); … }

  OC::PlatformConfig mPlatformConfig;
  void init() {
    mPlatformConfig = OC::PlatformConfig
        (OC::ServiceType::InProc,
         OC::ModeType::Client, // different than S
         "0.0.0.0", 0, // on any random port available
         OC::QualityOfService::LowQos // or HighQos
         );
    OCPlatform::Configure(mPlatformConfig);
  }
};
```

Registration of resource on Server

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IoTivity Server

IP Network

IoTivity Client(s)

OCPlatform::Configure(PlatformConfig) **OCPlatform::registerResource(...)**	OCPlatform::Configure(PlatformConfig) OCPlatform::findResource(...)

```
class IoTServer { // (...)
    OCResourceHandle mResource;
    OC::EntityHandler mHandler; // for CRUDN operations
    void setup() { // (...)
        result = OCPlatform::registerResource(mResource, // handle for resource
            "/BinaryRelayURI", // Resource Uri,
            "oic.r.switch.binary", "oic.if.baseline" // Type & Interface (default)
            mHandler // Callback to proceed GET/POST (explained later)
            OC_DISCOVERABLE | OC_OBSERVABLE // resource flags
           );
       OCPlatform::bindTypeToResource(mResource, … ); // optionally
}    };
```

Resource discovery on client : finding

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IoTivity Client(s)

OCPlatform::Configure(OC::PlatformConfig) OCPlatform::registerResource(...) { OCPlatform internal }	OCPlatform::Configure(OC::PlatformConfig) **OCPlatform::findResource**(OC::FindCallback) IoTClient::onFind(OCResource)

```
class IoTClient{ // ...
    OC::FindCallback mFindCallback;
    void onFind(shared_ptr<OCResource> resource);
    void setup() { //…
        mFindCallback = bind(&IoTClient::onFind, this, placeholders::_1); //C++11 std::bind
        OCPlatform::findResource("", // default
            "/oic/res", // CoAP endpoint, or resource based filtering for switches
            CT_ADAPTER_IP, // connectivityType can BT, BLE or other supported protocol
            mFindCallback, // to be called on Server response
            OC::QualityOfService::LowQos // or HighQos
        );
 } };
```

Resource discovered on client

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IoTivity Client(s)

OCPlatform::Configure(OC::PlatformConfig)
OCPlatform::registerResource(...)
{ OCPlatform internal }

OCPlatform::Configure(OC::PlatformConfig)
OCPlatform::findResource(OC::FindCallback)
IoTClient::onFind(OCResource)

```
class Resource { OCResourceHandle mResourceHandle; }; // Our resource for CRUDN

class IoTClient { // (…)
    std::shared_ptr<Resource> mResource;
    void onFind(shared_ptr<OCResource> resource)  {
        if (“/BinarySwitchURI” == resource->uri())
            mResource = make_shared<Resource>(resource);
    }
};
```

Resource discovering on client

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IoTivity Client(s)

OCPlatform::registerResource(...) IoTServer::**handleEntity**(OCResourceRequest	OCPlatform::findResource(...) IoTClient::mResource->**post**()

```
void IoTServer::setup() { //...
    OC::EntityHandler handler = bind(&IoTServer::handleEntity, this, placeholders::_1);
    OCPlatform::registerResource( … handler … );  ...
}
IoTServer::handleEntity(shared_ptr<OCResourceRequest> request) {
       string requestType = request->getRequestType();
       if ( requestType == “POST” ) { handlePost() } else { … }
       auto response = std::make_shared<OC::OCResourceResponse>(); //...
       OCPlatform::sendResponse(response);
 }
void IoTServer::handlePost(...) {}
```

Resource representation

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IoTivity Client(s)

OCPlatform::registerResource(...)
IoTServer::handleEntity(OCResourceRequest)
IoTServer::handlePost(OCResourceRequest)

OCPlatform::findResource(...)
IoTClient::mResource->**post**(false)

```
void Resource::post(bool value) {
   OCRepresentation rep;  QueryParamsMap params;
   rep.setValue("value", value); // property
   mOCResource->post(rep, params, mPostCallback);
```

```
 IoTServer::handlePost(shared_ptr<OCResourceRequest> request) {
    OCRepresentation requestRep = request->getResourceRepresentation();
    if (requestRep.hasAttribute("value")) {
          bool value = requestRep.getValue<bool>("value");
          cout << "value="<<value<<endl; // OR set physical IO (GPIO...)
}  }
```

GET / POST using Entity Handler

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IoTivity Client(s)

```
OCPlatform::Configure(OC::PlatformConfig )
OCPlatform::registerResource(...)
```

```
OCPlatform::Configure(OC::PlatformConfig )
OCPlatform::findResource(...)
```

```
OC::EntityHandler(OCResourceRequest)  {
  switch(getRequestType) {
    case 'POST: // Create resource 1st
      …
    case 'GET' : // Retrieve current value
      ...
    case 'PUT' : // Not allowed for Switch
      ...
   OCPlatform::sendResponse(...);
     OCPlatform::notifyAllObservers();
 }}
```

```
OC::OCResource::post(...) // Create
    OC::PutCallback(...)
```

```
OC:ObserveCallback(...) // Notify
```

```
OC::OCResource::get(...) // Retrieve
    OC::GetCallback(...)
```

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"I'm not crazy. My **reality**
is just different from yours."
~ *Lewis Carroll*

Resource is physical, not a boolean !

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- General Purpose ~~Input~~ Output: **GPIO**
  - Set a voltage on electrical pin from userspace
- This can be set using Linux's **sysfs** (adapt to C/C++)
  - echo $n > /sys/class/gpio/**export** ; echo out > /sys/class/gpio/gpio$n/**direction**
  - echo 1 ; sleep 1 ; echo 0 > /sys/class/gpio/gpio$gpio/**value**
- Or faster with direct access (kernel registers...)
  - Even better using mapping library RAA (Along UPM for sensors drivers)
- So, server's "**entity handler**" should send signal on **POST/PUT** requests, that's all
  - IoTServer::**handleEntity() { ...** IoTServer::handlePut() … }
  - IoTServer::handlePut() { ~ write("**/sys/class/gpio/gpio$n/value" ,**"%d", requestRep.**getValue**<bool>("*value*")); }

Samsung ARTIK™ 10 GPIO pinout

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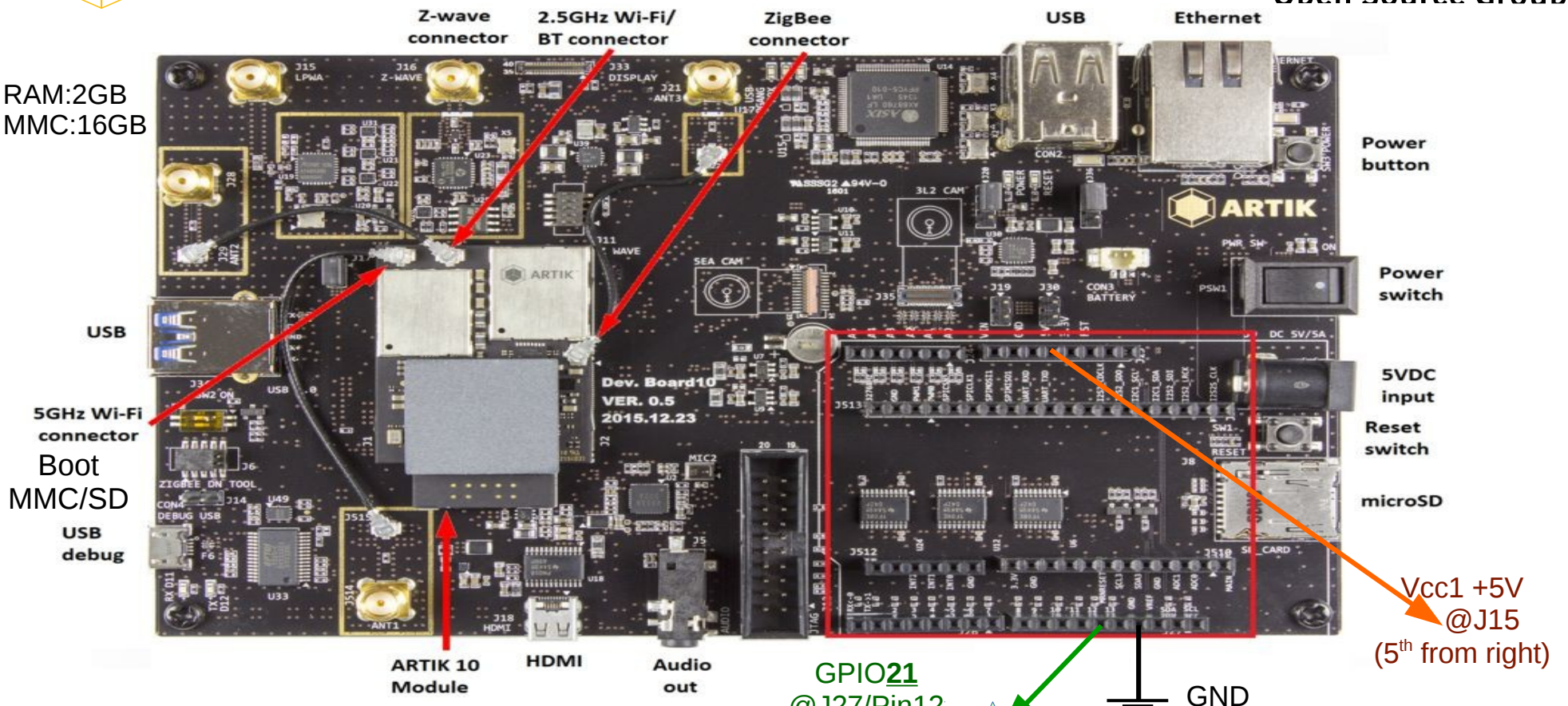

CPU: Exynos5 (4+4 Cores)

Hardware integration : DIY

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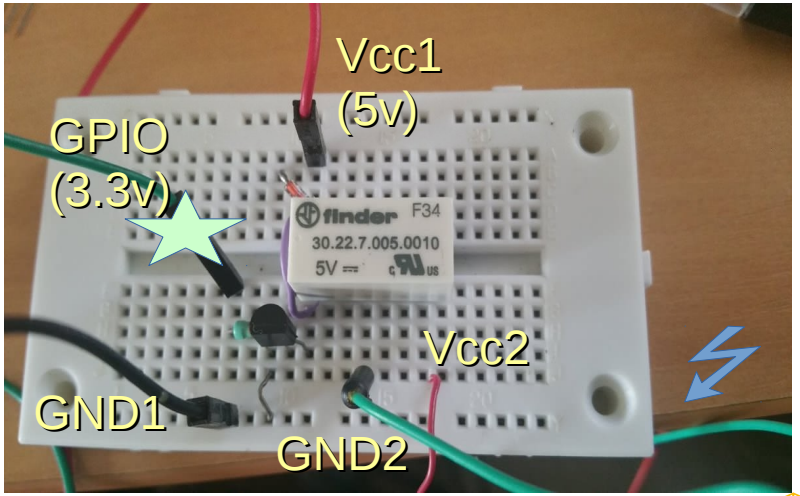
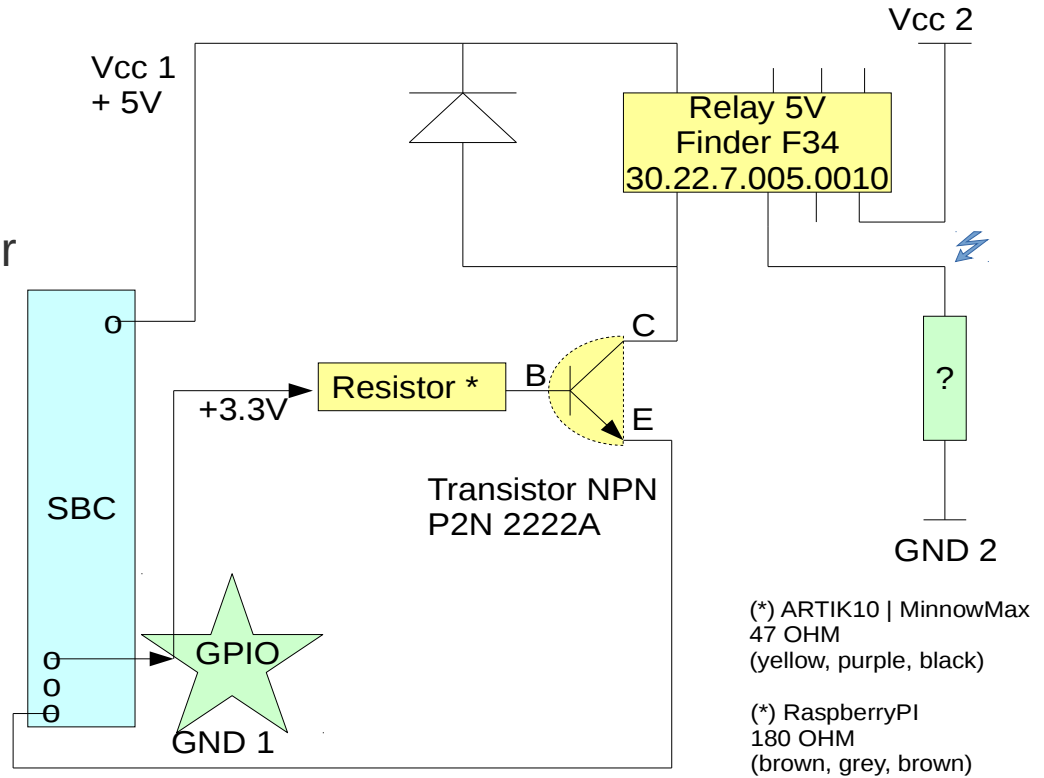
- High voltage relay (0-220V)
  - GPIO (3v3) < Relay (5V)
    - Signal Base of NPN Transistor





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Hardware integration, with modules

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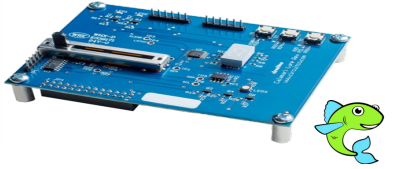
- Simples modules, to wire on headers
  - Ie: Single channel Relay (HXJ-36)
- Daughters boards, (compatibles headers)
  - Shields: for Arduino, and compatibles SBC (ARTIK10, Atmel Xpl)
  - Hats for Raspberry Pi+ (RabbitMax ships relay, I2C, IR, LCD)
  - Lures for Minnowboard (Calamari has buttons, Tadpole transistors)
- Warning: Arduino Mega's GPIO is 5V and most SBC are 3.3V



IoT devices are constrained !

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- If GNU/Linux is not an option for the computing power you have
  - Now let's port it to MCU using C
  - CSDK : iotivity/resource/csdk
  - Can use the same code base for Linux | Arduino...
- Example:
  - git clone -b csdk iotivity-example
  - git clone -b arduino iotivity-example
  - AVR binary Footprint : 116534 bytes for ATMega2560

IoTivity CSDK flow

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IoTivity Server

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IoTivity Client(s)

```
OCInit(NULL, 0, OC_SERVER);
OCCreateResource( …, handleOCEntity);
        {  OCProcess();  }
```

```
OCInit(NULL, 0, OC_CLIENT);
OCDoResource(...,OC_REST_DISCOVER, ...)
 handleDiscover(... OCClientResponse ...)
```

```
handleOCEntity(entityHandlerRequest) {
  switch (entityHandlerRequest->method
{
    case 'POST:  // CREATE resource 1st

    case 'GET' : // READ current value

    case 'PUT' : // then UPDATE value
      ...
     OCDoResponse(&response);
 }}
```

```
OCDoResource(...OC_REST_POST …)
 handlePost(... OCClientResponse ...)
```

```
OCDoResource(...OC_REST_GET …)
 handleGet(... OCClientResponse ...)
```

```
OCDoResource(...OC_REST_PUT …)
 handlePut(... OCClientResponse ...)
```

Interaction with other OS / Devices

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- Consumer electronics products
  - Tizen ❤ IoTivity
    - Tizen:3 contains as platform package (.rpm)
    - Tizen:2 can ship lib into native app (.tpk)
      - For Samsung Z1 (Tizen:2.4:Mobile)
      - Samsung GearS2 (Tizen:2.3.1:Wearable)
- GNU/Linux:
  - Yocto (Poky, AGL, GENIVI, OstroOS)
- Other OS too:

TIZEN™

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"Any sufficiently
advanced technology
is indistinguishable
from **magic**."
~ *Arthur C. Clarke*

Demonstration: tizen-artik-20161010rzr

https://vimeo.com/186286428#tizen-artik-20161010rzr

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Want More ?

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- More security, enable it, device provisioning, iotcon...
- More constrained: iotivity-constrained (RIOT, Contiki, Zephyr)
- More connectivity: BT, BLE, Zigbee, LTE, NFC...
- Scale: Deploy an OCF network of sensors, establish rules.
  - Global: Webservices (WSI), with cloud backend
  - For Smart (Home | Car | City | $profile)

Conclusion

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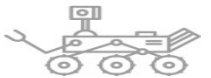
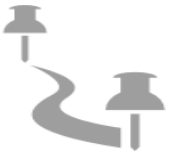
- Prototyping an IoT device is possible
  - with IoTivity IoT framework, that provides
    - Device to Device seamless connection
    - Create, Read, Update, Delete Resource & Notification
      - Can be easly implemented In C or C++
  - On Single Board Computers supporting Linux
- To work with devices supporting OCF standard protocol
  - Or supporting IoTivity like Tizen Wearables
- Possibilities are infinites

References

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- Entry point:
  - https://wiki.iotivity.org/examples
- Technical references
  - https://openconnectivity.org/resources/iotivity
    - OIC_1.1_Candidate_Specification.zip
  - https://wiki.iotivity.org/sources
  - http://elinux.org/ARTIK
- Keep in touch online:
  - https://wiki.iotivity.org/community
  - https://wiki.tizen.org/wiki/Meeting
  - https://developer.artik.io/forums/users/rzr
  - https://blogs.s-osg.org/author/pcoval/

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Danke Schoen !
Thanks / Merci / 고맙습니다

Samung OSG, SSI,
Open Connectivity Foundation, LinuxFoundation,
FLOSS Communities: Tizen, Yocto, EFL, AGL, GENIVI
FlatIcons (CC BY 3.0) : Freepik, Chao@TelecomBretagne,
Libreoffice, openshot,
SRUK,SEF, Intel, Rabbitmax,
ELC/OpenIoT attendees,
YOU !

Contact:
https://wiki.tizen.org/wiki/User:Pcoval

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Q&A or/and Annexes ?

Demonstration: iotivity-arduino-20161006rzr

https://vimeo.com/185851073#iotivity-arduino-20161006rzr

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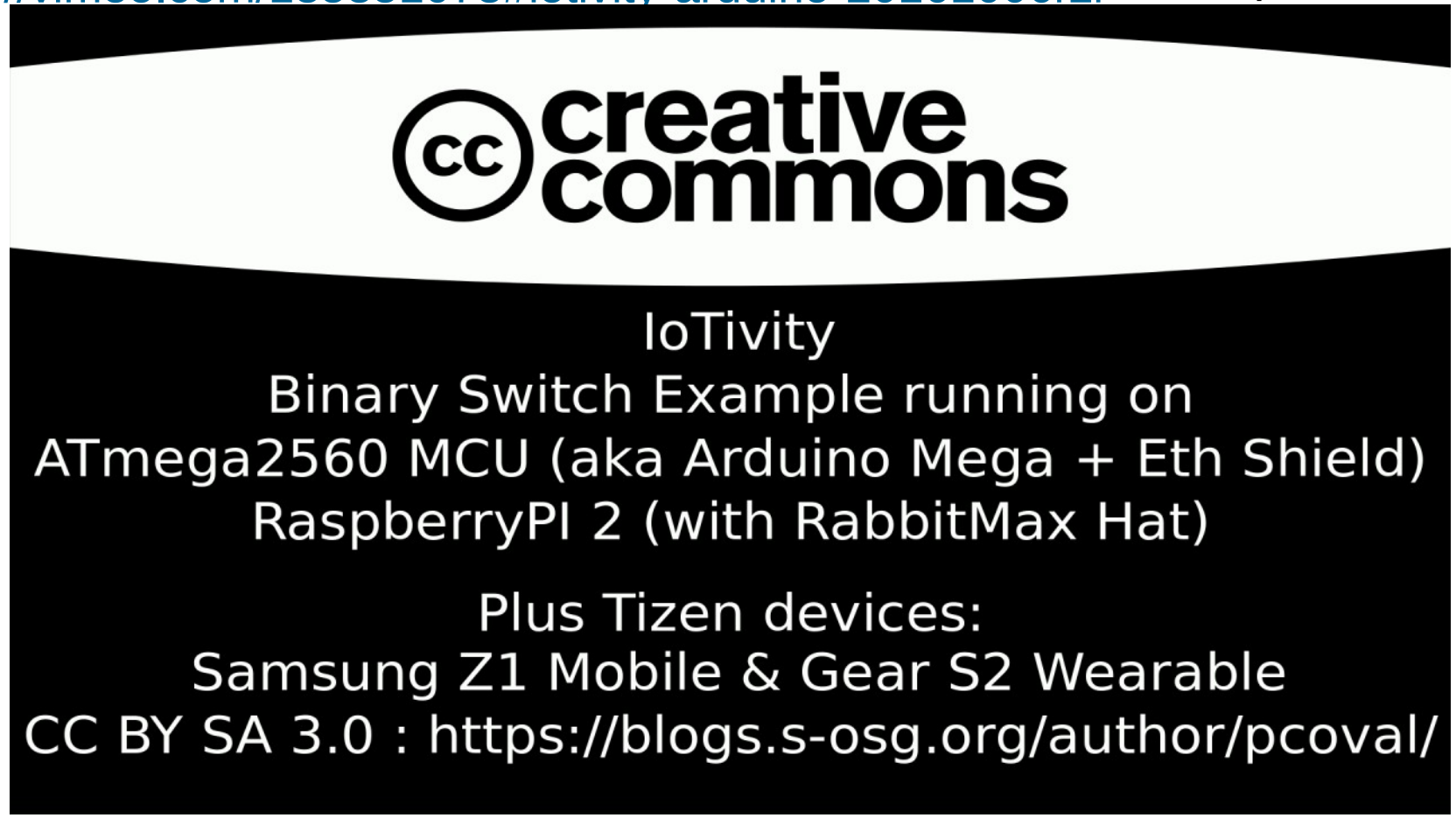

Simulator: Importing model, Resource served

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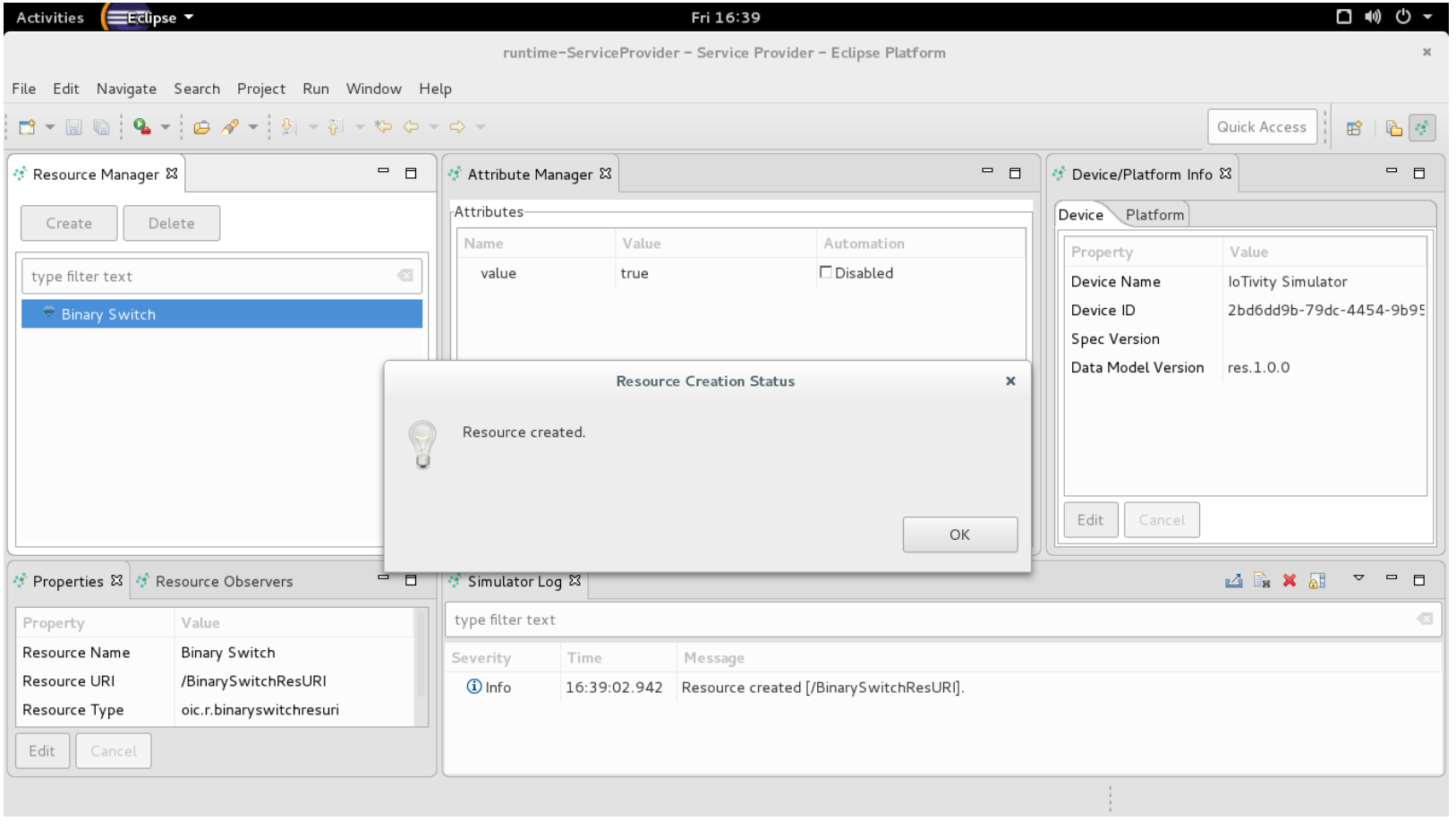

Client discovered Resource

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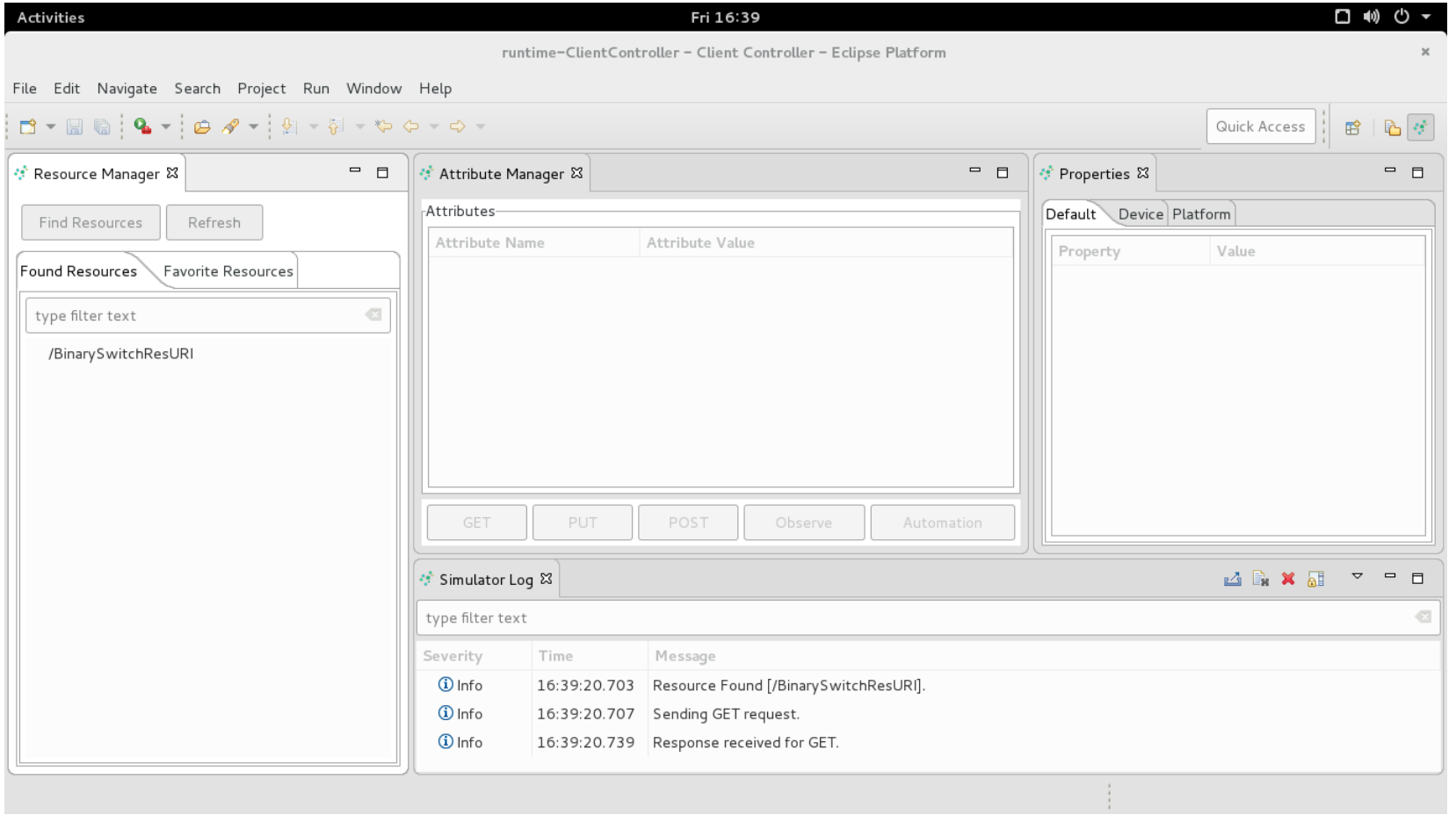

Resources properties on client

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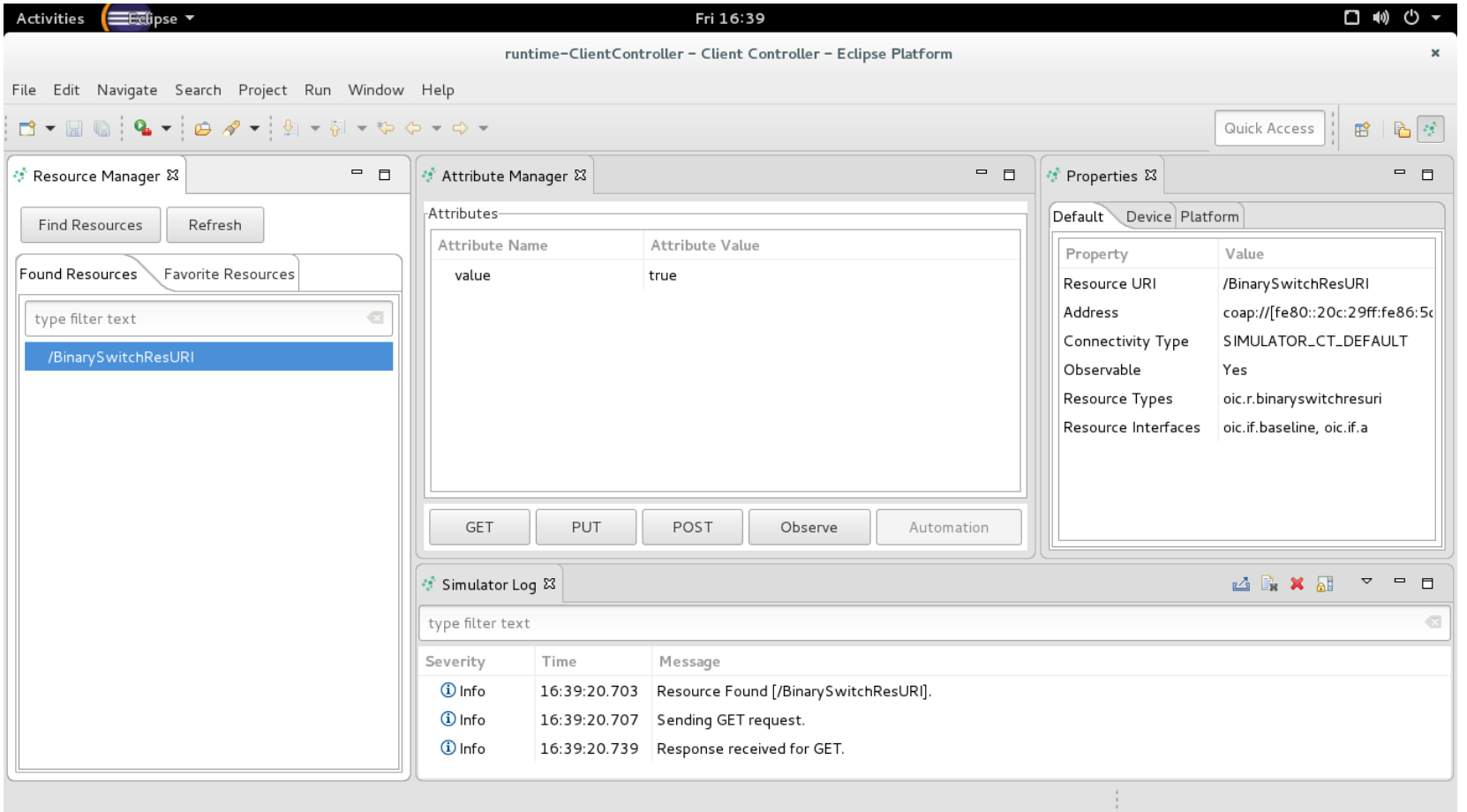

Attempt to change property using PUT

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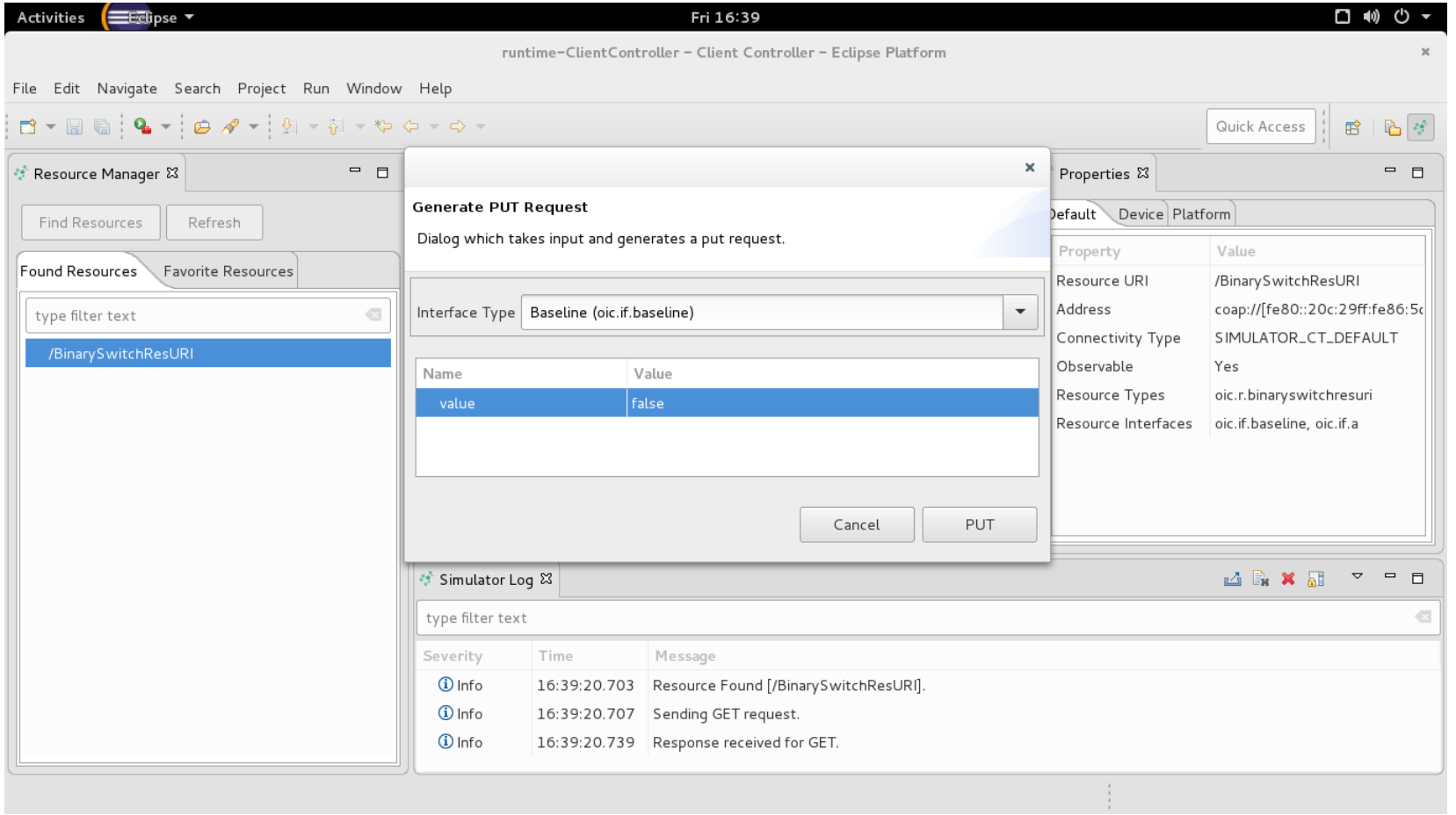

Failed, as unsupported by interface from model

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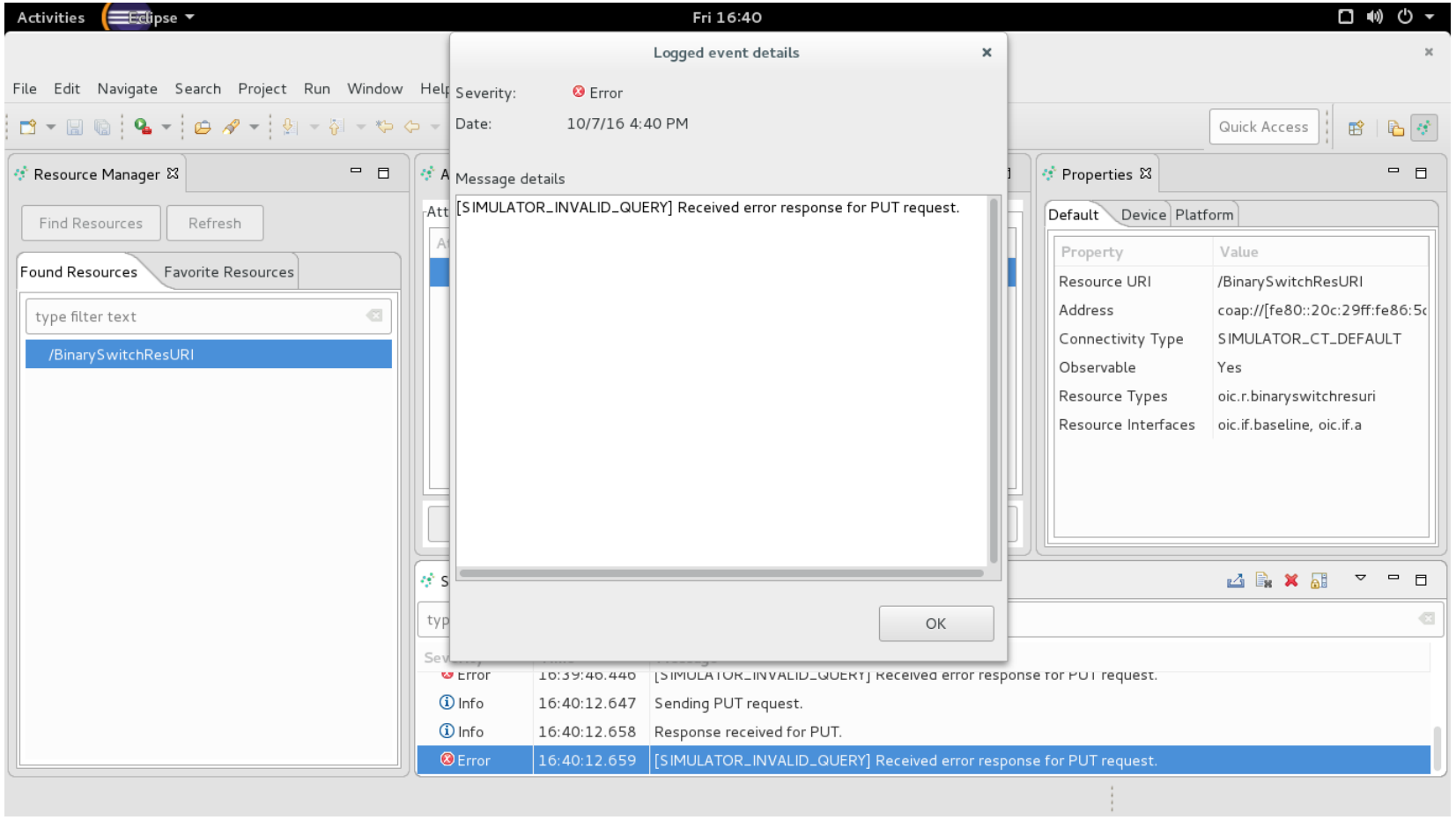

Client sets resource property using POST

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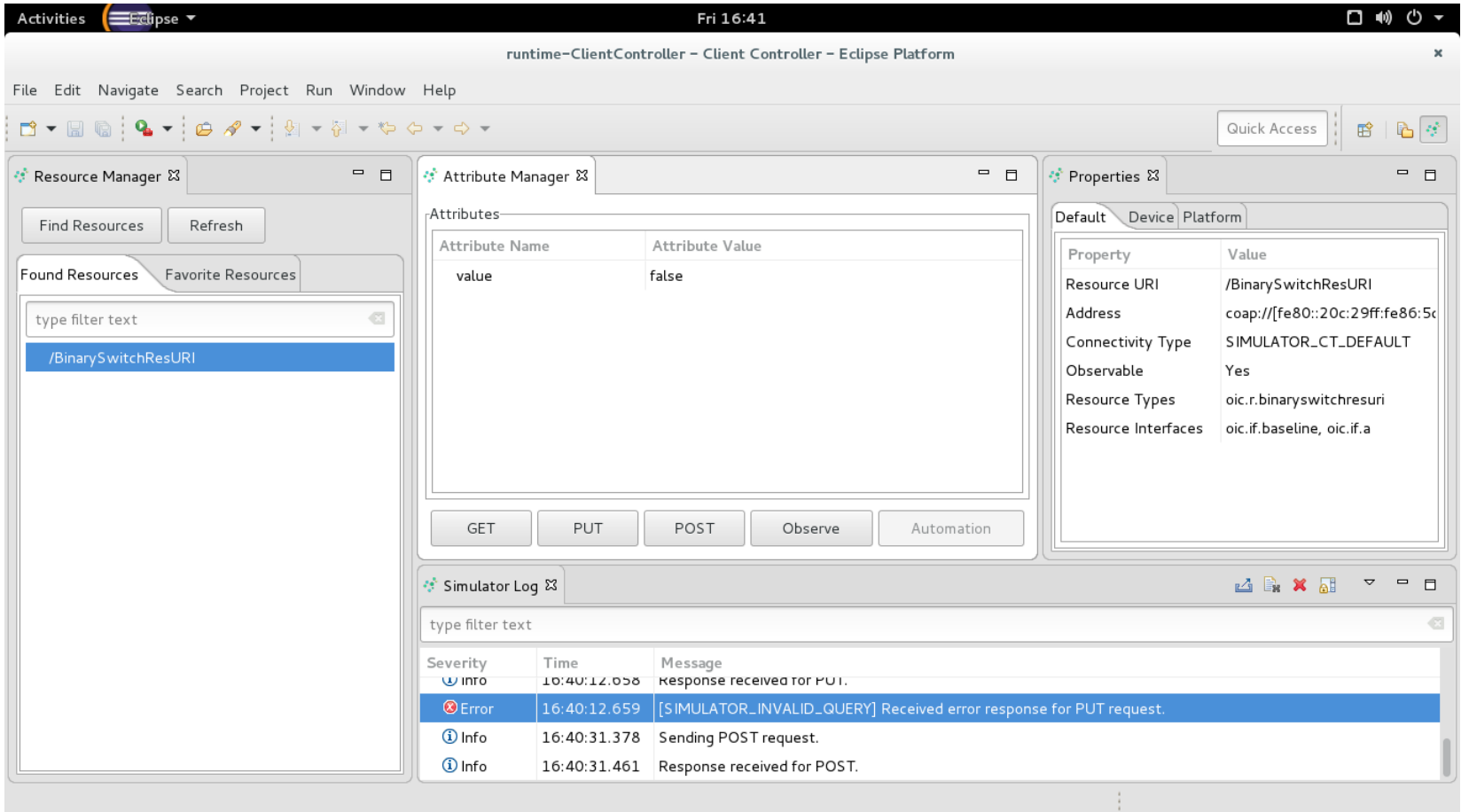

Server receives request and updates property

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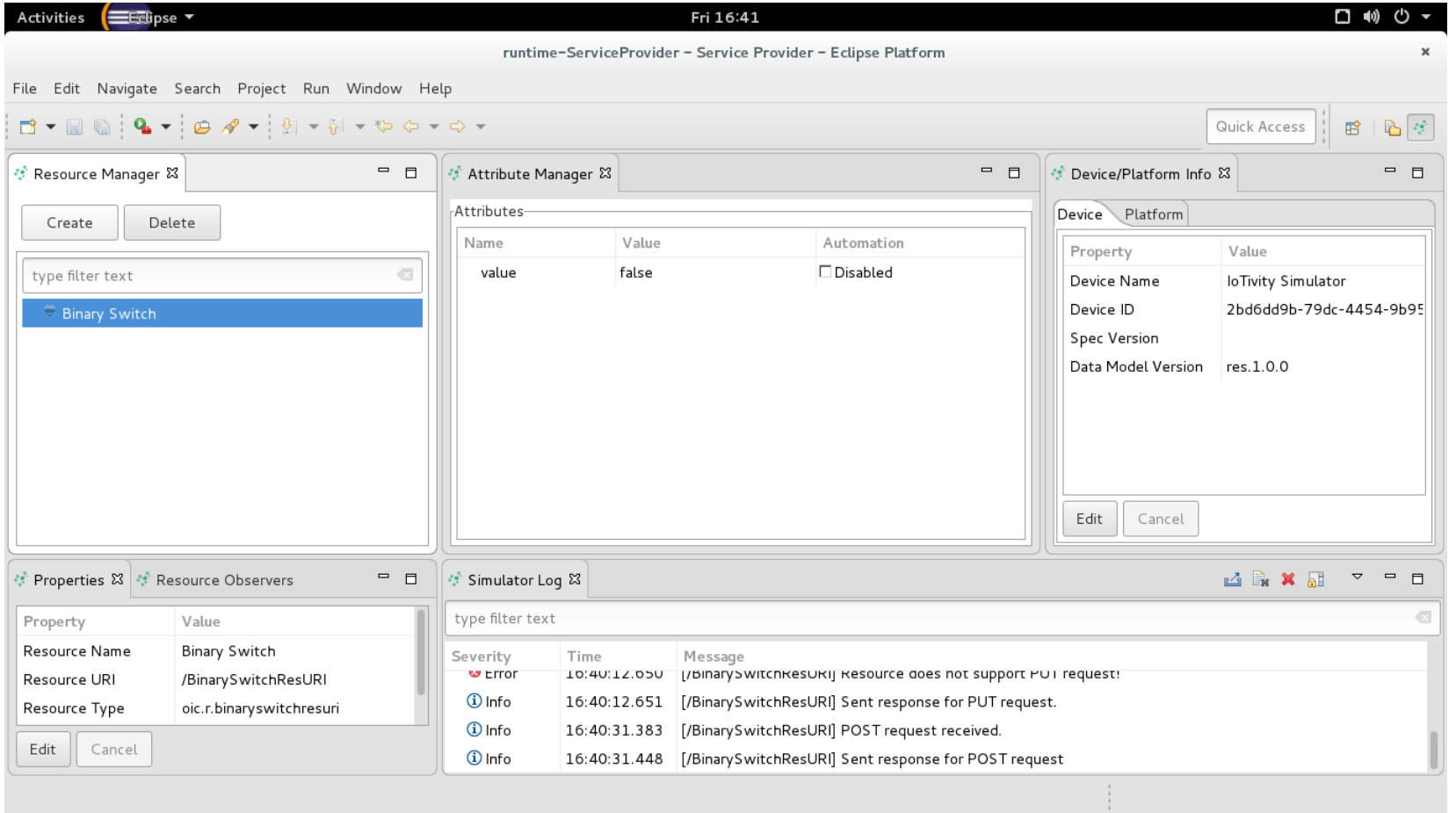


Technical Showcase

CE Workgroup Linux Foundation / Embedded Linux Conference Europe

Tizen devices connected with IoTivity

Phil Coval / Samsung OSG

SAMSUNG Open Source Group

What is demonstrated

IoTivity

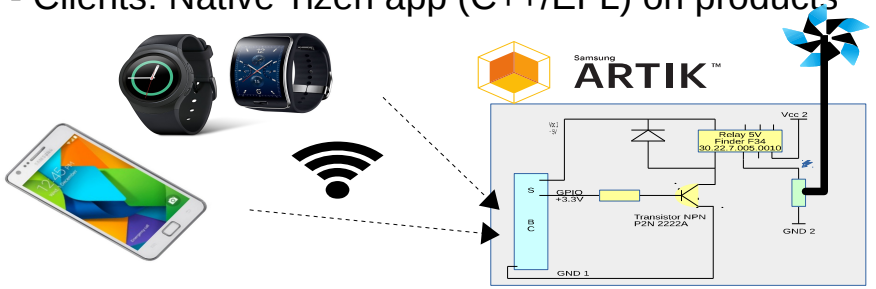
Seamless device to device connectivity framework

TIZEN

Linux-based software platform for consumer electronics

Demo: “Tizen DIY IoT Fan” controlled by devices

- Server: Tizen:Common on ARTIK dev board
- Clients: Native Tizen app (C++/EFL) on products



Hardware Information

ARTIK 10 (Exynos 5422 http://elinux.org/ARTIK)

Z1, Gear S (https://wiki.tizen.org/wiki/Devices)

What was improved

Tizen:Common 2016

- ARTIK 5 & 10 as latest reference devices
- Graphics: Enlightenment on Wayland

IoTivity 1.2.0

- Notification service
- Cloud features
- OS Support (Windows)
- CoAP (TSL, HTTP)
- UPnP bridge
- Extending support:
  - New OS: Windows, macOS
  - Linux: Tizen, Yocto, Debian, WRT...
  - Hardware: x86, ARM, RPi, MCU (Arduino)

Yocto project efforts (meta-oic, meta-artik...) yocto PROJECT

Source code or detail technical information availability

https://wiki.tizen.org/wiki/User:Pcoval

https://wiki.iotivity.org/community